

**ICESat-2 Controlled Document**  
**Released by: N. Brown 04/20/2011**

**ICE, CLOUD, and land Elevation Satellite-2  
(ICESat-2) Project**

**Advanced Topographic Laser Altimeter  
System (ATLAS)  
Receiver Telescope  
Integrated Product Specification  
ICESat-2-OPT-SPEC-0331**

**Revision (-)**  
**Effective Date: April 19, 2011**



**National Aeronautics and  
Space Administration**

**Goddard Space Flight Center  
Greenbelt, Maryland**

## CM FOREWORD

This document is an Ice, Cloud, and Land Elevation (ICESat-2) Project signature-controlled document. Changes to this document require prior approval of the applicable Product Design Lead (PDL) or designee. Proposed changes shall be submitted in the ICESat-2 Management Information System (MIS) via a Signature Controlled Request (SCoRe), along with supportive material justifying the proposed change.

In this document, a requirement is identified by “shall,” a good practice by “should,” permission by “may” or “can,” expectation by “will,” and descriptive material by “is.”

Questions or comments concerning this document should be addressed to:

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\*\*\* Signatures are available on-line at: <https://icesatimis.gsfc.nasa.gov> \*\*\*

## CHANGE RECORD PAGE

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## 1.0 SCOPE

This is the telescope integrated product specification document. This specification establishes the requirements for the performance, design, and manufacture of the Advanced Topographic Laser Altimeter System (ATLAS) receiver telescope. The accompanying Statement of Work (ICESat-2-OPT-SOW-0073) describes the procedures and reporting required by the contractor for the manufacture of the telescopes.

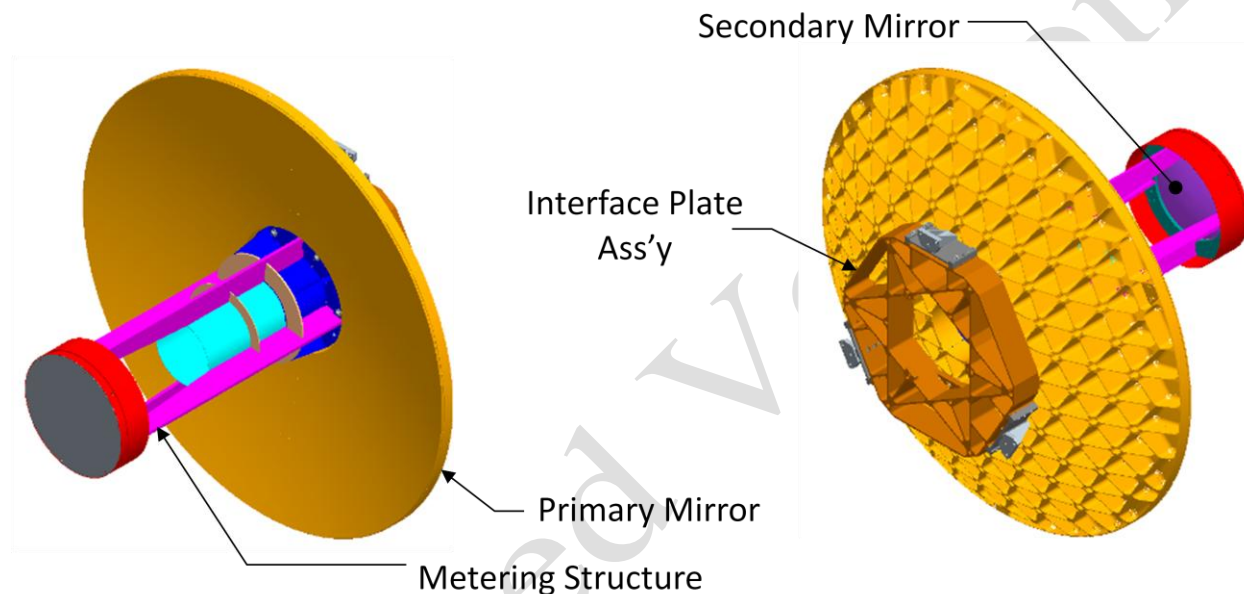
It should be understood by the Contractor that the telescope will not be formally accepted by Goddard Space Flight Center (GSFC) until GSFC has verified that all requirements have been satisfied. This includes, but is not limited to, any requirements that must be verified through testing at GSFC.

### 1.1 Introduction

The ATLAS telescope is based on the beryllium (I-220-H) telescope design used on the Geoscience Laser Altimeter System (GLAS). However, the ATLAS telescope will differ from the GLAS telescope in many respects including size, optical prescription and optical performance requirements. The primary mirror (M1) will be a light-weighted concave mirror. The secondary mirror (M2) will be a solid convex mirror.

## 2.0 Telescope concept

Telescopes used on previous missions have all employed the same general design consisting of a primary mirror, a secondary mirror, a metering structure and an interface plate assembly. The primary and secondary mirrors provide the optical surfaces, while the metering structure maintains the appropriate spacing between them. An interface plate assembly attached to back of the primary mirror is used to mount the telescope on the optical bench. Refer to Figure 2-1 for an illustration of this concept.

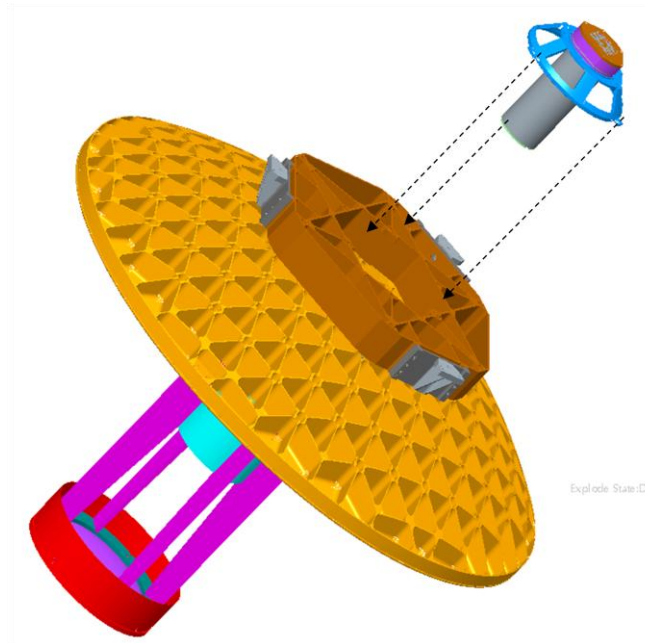


**Figure 2-1 – An Illustration of the Major Sub-assemblies Used on the GLAS Telescope**

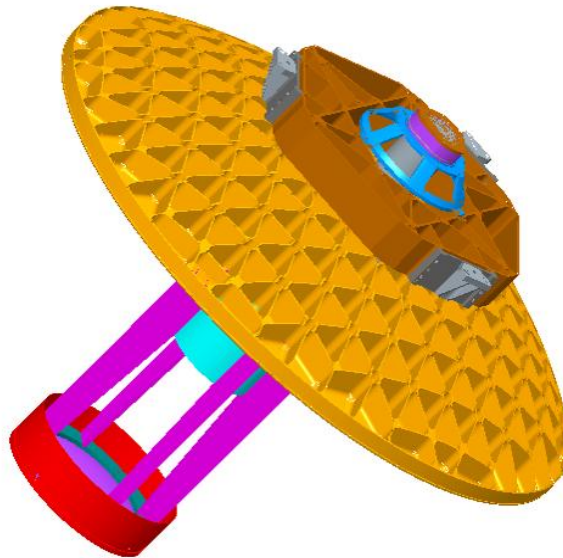
In addition to providing a mounting plane to the optical bench, the interface plate assembly also provides a mounting plane for the ATLAS aft optics, which will be used to correct the telescope off-axis imaging. Refer to Figure 2-2 and Figure 2-3 for illustration regarding the aft optics and how they mount to the interface plate assembly. It is imperative for the aft optics to maintain proper alignment to the telescope's optical axis, for this reason the interface plane of the aft optics is defined in this document.

It should be clear to all parties that the Contractor is only responsible for providing the interface for the aft optics and is *not* responsible for supplying the aft optics or verifying the performance of the telescope w/ the aft optics attached.

Additional information, including drawings, on telescope designs used on other projects will be made available to the Contractor if requested.



**Figure 2-2 – An Illustration of the Aft Optics Aligning to the Telescope's Interface Plate Assembly**



**Figure 2-3 – An Illustration of the Aft Optics Mounted to the Telescope's Interface Plate Assembly**

### 3.0 DOCUMENTATION

#### 3.1 Applicable Documents

The following documents provide information Applicable (i.e., binding/required) to the ATLAS telescope. These documents are applicable in their entirety. Since these documents are subject to periodic revisions, the user should refer to the latest available version. In the event of a conflict between this document and the documents referenced herein, the documents listed below will take precedence.

1. GSFC-STD-1000, Rules for Design, Development, Verification and Operation of Flight Systems
2. ICESat-2-ATSYS-PLAN-0297, ATLAS Contamination Control Plan
3. ICESat-2-ATSYS-REQ-0517, ATLAS Component Environmental Requirements
4. ICESat-2-ATSYS-REQ-0479, ATLAS Technical Allocation Requirements Document
5. ICESat-2-MECH-IFACE-0590, ATLAS Component Mechanical Interface Control Document
6. ICESat-2-OPT-SOW-0073, ATLAS Flight Telescope Statement of Work
7. ICESat-2-REC-REQ-0488, ATLAS Receiver Level IV Requirements Document
8. ICESat-2-OPT-REQ-0600, ATLAS Receiver Telescope Assembly (RTA) Level V Requirements Document
9. ICESat-2-SMA-PLAN-0032, Beryllium Safety Plan
10. ICESat-2-SYS-REQ-0189 ESR131, ATLAS Electrical Systems Requirements
11. ICESat-2-THM-IFACE-0214, ATLAS Thermal Interface Control Document
12. MIL-STD-810F, Fungus Inert Materials
13. MIL-STD-889, Protection Against Corrosion
14. MSFC-STD-3029, Stress Corrosion Cracking
15. 541-PG-8072.1.2, Critical Ground Support Equipment Fasteners
16. ASTM E 1417, Standard Practice for Liquid Penetrant Inspection
17. NASA-STD-5009, Non-Destructive Evaluation Requirements For Fracture-Critical Metallic Components
18. MIL-M-13508C, Mirror, Front Surface Aluminized: For Optical Elements
19. MIL-C-48497A, Durability Requirements for Coating, Single or Multilayer, Interference

#### 3.2 Reference Documents

1. ATLAS Receiver Telescope Optical Design Rev A, Luis Ramos-Izquierdo, 3/31/11
2. ICESat-2-ATSYS-TN-0190, ATLAS Instrument Predicted Performance
3. ICESat-2-ATSYS-RPT-0485, ATLAS Performance Model Description
4. ICESat-2-THM-LIST-0520, ATLAS Thermal Analysis Approved Optical Properties List

5. GEVS-STD-7000, General Environmental Verification Standard For GSFC Flight Programs and Projects

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#### 4.0 Telescope Prescription & Performance

**TSCOPE001** - The telescope shall be of the type Ritchey–Chrétien.

Rationale: NASA plans to implement the required 0.9 degree diameter ATLAS receiver field of view (FOV) using a specially built aft optics assembly and the Ritchey–Chrétien telescope configuration.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification: Inspection

**TSCOPE002** – The on-axis blur circle diameter shall be less than or equal to 32 micrometer ( $\mu\text{m}$ ) at 80% encircled energy.

Rationale: The blur circle diameter specification is the critical parameter for evaluating this telescope. Surface figure is derived from this parameter.

Traceability: TAR10 (ATLAS Technical Allocation Requirements Document, ICESat-2-ATSYS-REQ-0479)

Verification Method: Testing

**TSCOPE003** - The telescope shall have throughput greater than or equal to 80%, which includes both mirror coating reflectance and secondary mirror and spider obscuration (vignetting).

Rationale: The predicted instrument performance, documented in ICESat-2-ATSYS-TN-0190, is based on mean signal photoelectrons received per channel, as described in ICESat-2-ATSYS-RPT-485, ATLAS Performance Model Description. The receiver system allocation is derived from the total end-to-end system optical throughput required to meet required performance. Receiver system optical throughput allocation is a portion of the total based on the current best estimates as of 3-4-11 with appropriate contingency based on design maturity.

Traceability: TAR7 (ATLAS Technical Allocation Requirements Document, ICESat-2-ATSYS-REQ-0479), without telescope blanket obscuration term.

Verification Method: Testing (coating witness samples), Inspection & Analysis (vignetting terms)

## 5.0 TELESCOPE ASSEMBLY REQUIREMENTS

**TSCOPE004** - The primary mirror to secondary mirror vertex spacing shall be nominally 463.36 millimeters (mm) and adjustable via shims to meet requirements TSCOPE005 & TSCOPE006.

Rationale: This information is provided as an aid to the Contractor.

Traceability: Derived from the optical system design to meet effective focal length (EFL) and back focal length (BFL) requirements.

Verification Method: Testing

**TSCOPE005** – The telescope effective focal length shall be  $3798 \text{ mm} \pm 18 \text{ mm}$  (3797.71 mm nominal optical).

Rationale: These specifications meet the telescope plate scale requirements

Traceability: Derived from the optical system design to meet FOV alignment requirements.

Verification Method: Test (Accuracy of measurement to be specified by Contractor)

**TSCOPE006** - The telescope back focal distance, measured from the primary mirror vertex to the focal plane, shall be:  $192 \text{ mm} \pm 2 \text{ mm}$  (192.015 mm nominal optical design).

Rationale: This specification is necessary to meet the aft optics assembly interface requirements.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Test

**TSCOPE007** – The opto-mechanical axis error shall be less than or equal to 0.1 milliradian (mrad). This error is defined as the angle between the telescope optical axis and the normal to the plane defined by the three flexure mounting pads of the interface plate.

Rationale: This specification enables the system to meet instrument level boresight alignment requirements.

Traceability: Derived from adjustment range on laser assembly output Risley pair

Verification Method: Testing

**TSCOPE008** – The telescope optical axis total deflection, under 1-G loading, shall be [20 microradians ( $\mu$ rad) from the ideal optical axis.

Rationale: Much of the instrument optical alignment during I&T will be performed with the telescope mounted such that the optical axis is parallel to the ground. Since the alignment will take place in a 1-G environment but the telescope will operate in space with no gravity load, it is important that the gravity release effects on the telescope's optical alignment be small.

Traceability: Derived from the optical system design to meet instrument boresight alignment requirements.

Verification Method: Testing and Analysis

**TSCOPE009** - The telescope shall provide an interface behind the primary mirror (M1), with shear features<sup>1</sup>, to allow for mounting of GSFC supplied aft optics. The interface will be known as the Interface Plate Assembly.

Rationale: The telescope and aft optics together improve field performance.

Traceability: Derived from the optical system design to meet FOV requirements.

Verification: Inspection

**TSCOPE010** - The Interface Plate Assembly shall provide for flexure mounting to an optical bench.

Rationale: Flexures will ensure that optical bench structural loads and thermal loads are mitigated.

Traceability: Derived to meet stability requirements.

Verification: Inspection

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<sup>1</sup> A "shear feature" is any feature that reacts shear forces and prevents/minimizes displacement in the direction of load. Shear features are used in many optical applications to ensure alignment critical optics do not shift once aligned. Liquid pinning is one technique commonly employed as a shear feature. GSFC will evaluate other techniques as suggested by the Contractor.

**TSCOPE011** – The Interface Plate Assembly shall provide a separate mounting plane for the aft optics perpendicular to the optical axis to within 500 microradian ( $\mu$ rad).

Rationale: In order to meet performance requirements, the aft optics mounting plane must be perpendicular to the optical axis.

Traceability: Derived from the Optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification: Inspection and testing.

**TSCOPE012** – The aft optics mounting plane shall be concentric to the optical axis to within a true position of 0.12 mm on the diameter under maximum material conditions (the aft optics mounting plane on the Interface Plate Assembly will serve as the primary datum and the optical axis will serve as the secondary datum).

Rationale: In order to meet performance requirements, the aft optics mounting plane must be centered on the telescope optical axis.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification: Inspection and testing.

**TSCOPE013** – The telescope design shall include shear features at all alignment critical interfaces, including the interface to the optical bench.

Rationale: Ensures that the telescope is unable to shift once it has been aligned.

Traceability: Derived to meet stability requirements.

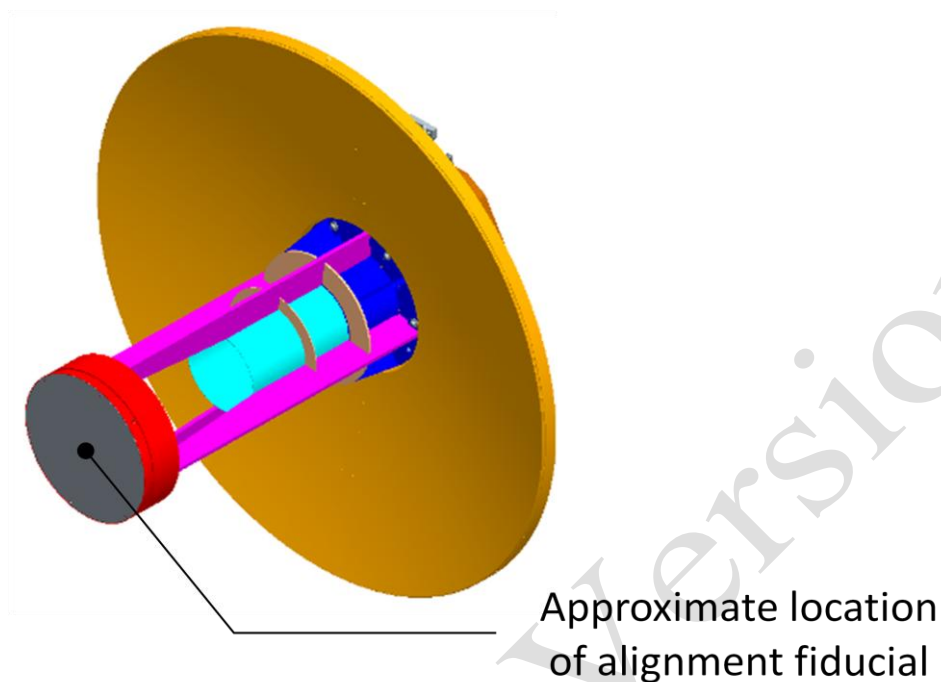
Verification: Inspection and analysis.

**TSCOPE014** – The telescope design shall include an optical alignment cube (Jenoptik ORC 0.5, ORC 0.75 or equivalent) w/ pattern, located behind the secondary mirror as shown in Figure 5-1.

Rationale: The optical alignment cube will be used in the alignment process and for subsequent testing. Mounting it behind the secondary mirror will ensure accessibility to the cube during later stages of I&T.

Traceability: Derived from the optical system design in order to meet alignment requirements.

Verification Method: Inspection



**Figure 5-1 - Approximate Location of the Optical Alignment Cube Behind the Secondary Mirror**

**TSCOPE015** – The alignment of the optical alignment cube shall be stable to within 10  $\mu$ rad of the telescope's optical axis after being subjected to all environments specified in this document.

Rationale: Since the optical alignment cube is used to measure deflections, it is crucial the structure the alignment cube mount to does *not* introduce additional deflection (i.e. – it should not be flimsy).

On several other projects alignment cubes have been bonded to a cover plate directly behind the secondary mirror. This approach has worked successfully in the past. Additional information will be made available upon request.

Traceability: Derived from the optical system design in order to meet alignment requirements.

Verification Method: Inspection & Analysis

**TSCOPE016** – The optical alignment cube shall be completely captured.

Rationale: It is vital that the alignment cube does not damage the telescope in the event the bond fails. One suggested solution is to provide a mechanically fastened cage around the cube that can be installed and remove as necessary. Additional information will be made available upon request.

Traceability: Derived from the optical system design in order to meet alignment requirements.

Verification Method: Inspection

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## 6.0 PRIMARY MIRROR DESIGN REQUIREMENTS

**TSCOPE017** – The primary mirror shall have clear aperture outside diameter of 800.0 mm  $\pm$ 1.0 mm and inside diameter 225.8 mm  $\pm$ 1.0 mm.

Rationale: The primary mirror clear aperture inner diameter (ID) and outer diameter (OD) are necessary to meet optical system performance requirements

Traceability: REC1102

Verification Method: Inspection

**TSCOPE018** - The primary mirror shall have a center hole of diameter 101.6 mm +1.0 mm/-0 mm.

Rationale: The primary mirror center hole diameter must be large enough to accommodate the aft optics FOV.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Inspection

**TSCOPE019** - The primary mirror vertex radius shall be 1120.000 mm  $\pm$ 2.240 mm (concave).

Rationale: The radius of curvature is necessary to meet optical performance requirements.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Testing (Contractor to provide interferogram).

**TSCOPE020** - The primary mirror conic constant shall be -1.00850  $\pm$ 0.00020.

Rationale: The correct conic constant is required to meet optical performance requirements.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Testing (Contractor to provide interferogram).

**TSCOPE021** - The primary mirror surface roughness *after polishing and coating* shall be less than or equal to 30 Å rms, 1-100 micron scan length.

Rationale: Specified surface finish will meet stray light requirements.

Traceability: Derived from GLAS heritage

Verification Method: Testing

**TSCOPE022** - The scratch and dig of the primary mirror shall be 60 – 40.

Rationale: Optical surface must have a minimum of blemishes

Traceability: Derived from GLAS heritage

Verification Method: Inspection

**TSCOPE023** - The primary mirror shall use a substrate thickness and lightweight pattern that results in an acceptable level of overall mirror deformation, stress, and print-through. The Contractor is welcome to use a design based on the GLAS primary mirror design as shown in Figure 6-1 and

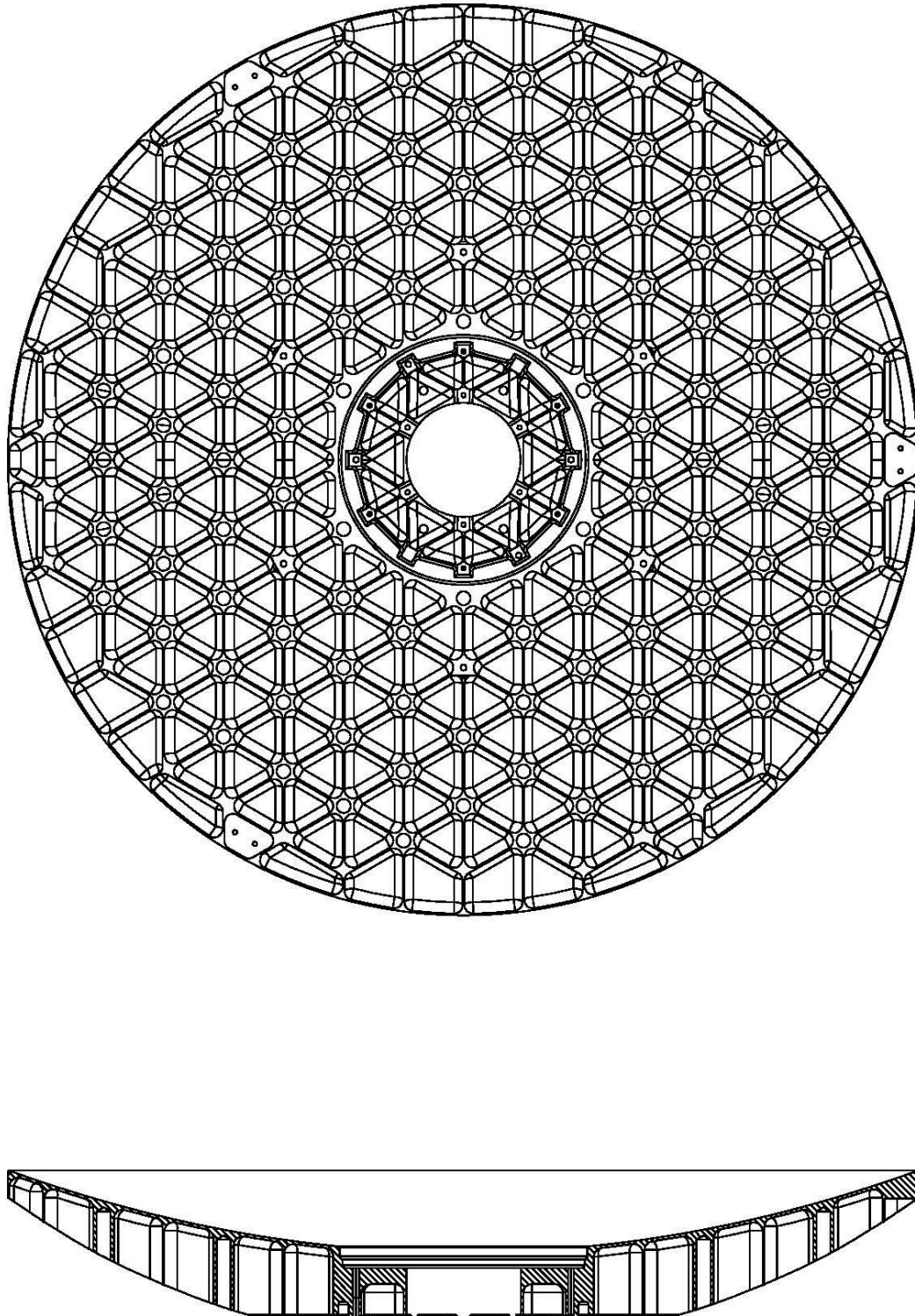


Figure 6-2. Alternate construction patterns are also welcomed, especially if they offer some stated advantage (for example, relative to cost &/or schedule). Detailed manufacturing drawings of the GLAS primary mirror will be made available upon request.

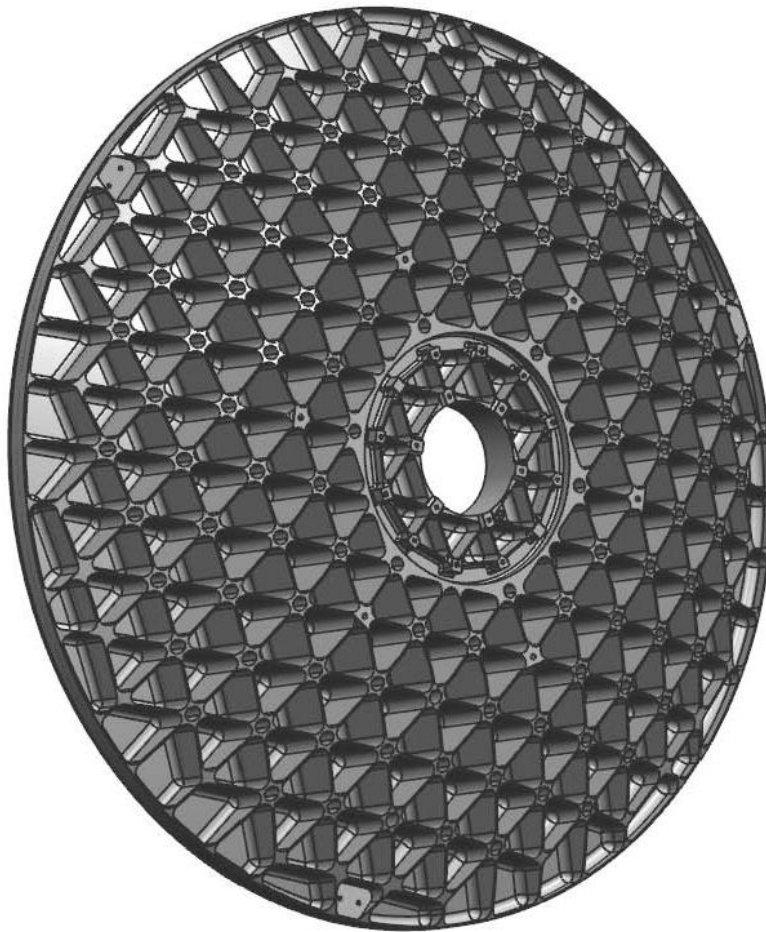
Rationale: The mirror thickness and substrate pattern used for the 1 meter (m) GLAS beryllium primary had acceptable levels of gravity deformation, fabrication/alignment & launch stress, and print through. Like the ATLAS primary mirror, the GLAS primary mirror was Electroless Nickel (EN) plated and had an enhanced aluminum coating on its optical surface. However, the ATLAS primary is 20% smaller in diameter (“D”) than GLAS. NASA recognizes that scaling the design of a lightweight mirror is complex. Relative to the light-weighting pattern & front-facesheet thickness, there are many designs that will work at our new diameter and still be acceptable. NASA desires the Contractor to choose a design of their own liking, especially if such a design offers costs and schedule advantages and still meets the needs for Interface Control Document (ICD) compliance, weight, mechanical/stress margins, and GLAS-like levels of overall and intercellular deflection.

Traceability: GLAS opto-mechanical design and ATLAS image quality requirement

Verification Method: Testing and Inspection



**Figure 6-1 – Wireframe Views Illustrating the Light-weighting Scheme Used on the GLAS  
1 m Telescope Primary Mirror**



**Figure 6-2 – A Shaded Isometric View Illustrating the Light-weighting Scheme Used on the GLAS 1-m Telescope Primary Mirror**

## 7.0 SECONDARY MIRROR DESIGN REQUIREMENTS

**TSCOPE024** - The secondary mirror clear aperture outside diameter shall be 160 mm +1/-0 mm and an inside diameter of 28 mm +0/-1 mm.

Rationale: The secondary mirror clear aperture ID and OD are necessary to meet optical system performance requirements

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Inspection

**TSCOPE025** - The secondary mirror vertex radius shall be 226.710 mm (convex)  $\pm 0.450$  mm.

Rationale: The radius of curvature is necessary to meet optical performance requirements.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Testing (Contractor to provide interferogram)

**TSCOPE026** - The secondary mirror conic constant shall be  $-1.89108 \pm 0.00100$ .

Rationale: The correct conic constant is required to properly define the shape of the mirror.

Traceability: Derived from the optical design implementation to meet performance requirements. (ATLAS Receiver Telescope Optical Design, Rev A – L. Ramos-Izquierdo, 3/31/11)

Verification Method: Testing

**TSCOPE027** - The secondary mirror surface roughness *after polishing and coating* shall be less than or equal to 20 Å rms, 1-100 micron scan length.

Rationale: Specified surface finish will meet stray light requirements.

Traceability: Derived from GLAS heritage

Verification Method: Inspection

**TSCOPE028** - The secondary mirror scratch and dig shall be 60 – 40.

Rationale: Optical surface must have a minimum of blemishes.

Traceability: Derived from GLAS heritage.

Verification Method: Inspection

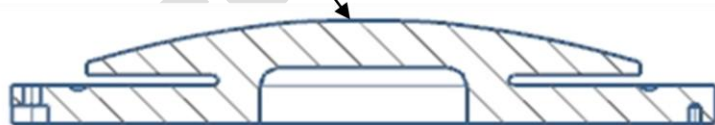
**TSCOPE029** - The secondary mirror shall have a 0.5mm diameter, black-dot optical fiducial, centered on the front of the mirror as shown in Figure 7-1.

Rationale: Fiducials are used in the alignment process and for subsequent testing.

Traceability: Derived from the optical system design in order to meet alignment requirements.

Verification Method: Inspection

Approximate location  
of Fiducial #1



**Figure 7-1 - Approximate Location of Alignment Fiducial on the Secondary Mirror**

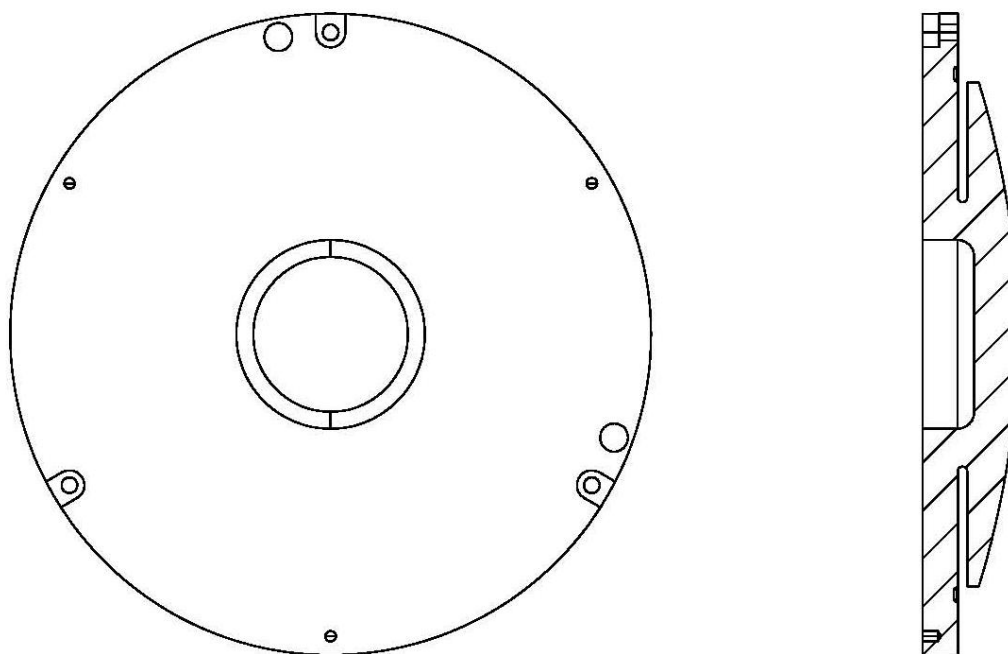
**TSCOPE030** – The solid secondary mirror shall use a substrate thickness that results in an acceptable level of overall mirror deformation and stress. The Contractor is welcome to use a design based on the GLAS secondary mirror design as shown in Figure 7-2. Alternate designs are also welcome, especially if they offer some stated advantage (for example, relative to cost &/or schedule). Detailed manufacturing drawings of the GLAS secondary mirror will be made available upon request.

Rationale: The mirror thickness used on the GLAS beryllium secondary mirror had acceptable levels of gravity deformation, fabrication/alignment and launch stress. Like the ATLAS secondary mirror, the GLAS secondary mirror was Electroless Nickel plated and had an enhanced aluminum coating on its optical surface. The ATLAS telescope has a wider FOV than GLAS, and the secondary is ~ 10% smaller in diameter (“D”) than GLAS. NASA recognizes that

scaling the design of a mirror is complex. NASA desires the Contractor to choose a mirror thickness of their own liking, especially if such a design offers costs and schedule advantages and still meets the needs for ICD compliance, weight, mechanical/stress margins, and GLAS-like levels of overall deflection.

Traceability: GLAS opto-mechanical design and ATLAS image quality.

Verification Method: Analysis, Inspection & Testing



**Figure 7-2 –An Illustration of the Secondary Mirror Used on the GLAS 1 m Telescope**

**TSCOPE031** – The secondary mirror shall include a baffle cover. It is recommended to the Contractor to use a baffle cover design based on the GLAS design shown in Figure 7-3 and Figure 7-4, which attached to the metering structure and was removable without impacting the secondary mirror. Detailed manufacturing drawings of the secondary mirror baffle cover will be made available upon request.

Rationale: A baffle cover is necessary to prevent stray light from affecting the incoming signal.

NASA desires the Contractor to choose a baffle design and thickness of their own liking, especially if such a design offers costs and schedule advantages and still meets the needs for ICD compliance, mechanical/stress margins, obscurations and FOV.

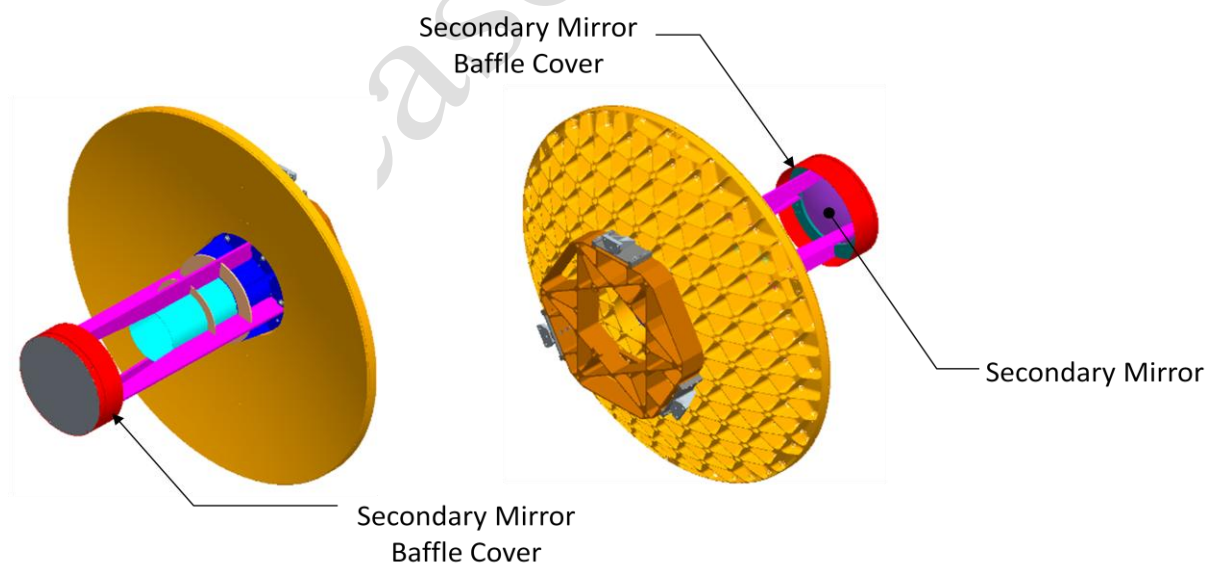
It should be noted that the final stray light analysis for the telescope will not be completed until well after the telescope(s) have been delivered. As such, the secondary mirror baffle cover design should allow for easy replacement, without impact to telescope performance, should the stray light analysis indicate a longer (or shorter) baffle length is required.

Traceability: Derived from GLAS heritage.

Verification Method: Analysis, Inspection, & Testing



**Figure 7-3 - A Graphic Showing the GLAS Secondary Mirror Baffle Cover**



**Figure 7-4 - An Image of the GLAS Secondary Mirror Baffle Cover mounted ion the GLAS 1 m Telescope**

**TSCOPE032** – The secondary mirror baffle cover design shall allow for replacement, without impact to telescope performance or alignment.

Rationale: The final stray light analysis for the telescope will not be completed until well after the telescope(s) have been delivered. As such, it may be necessary to replace the baffle cover should the stray light analysis indicate a longer (or shorter) baffle length is required.

Traceability: Derived from GLAS heritage.

Verification Method: Analysis, Inspection, & Testing

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## 8.0 Metering Structure Requirements

**TSCOPE033** - The metering structure of the telescope shall be machined entirely from a single billet of I-220-H Beryllium.

Rationale: Uncertainty in the brazing on the GLAS spare telescope metering structure led to the decision to hog-out the tower for the 0.8m telescopes.

Traceability: Derived from lessons learned.

Verification: Inspection

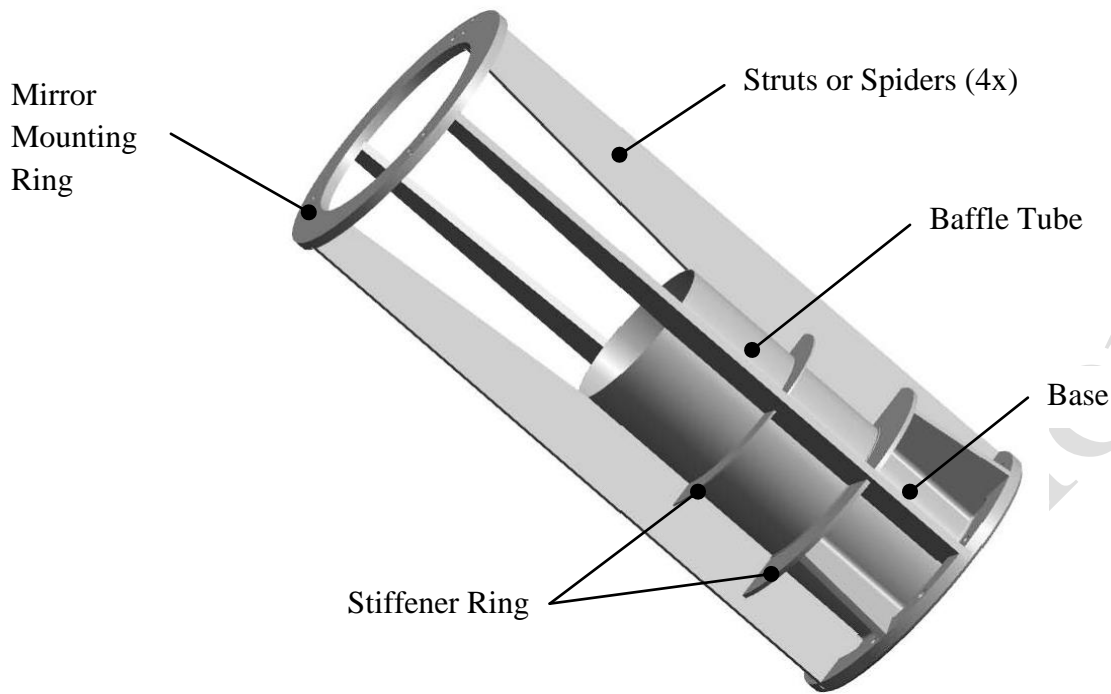
**TSCOPE034** – The metering structure shall include a baffle tube. It is recommended to the Contractor to use a baffle tube design based on the GLAS design shown in Figure 8-1 and Figure 8-2. Detailed manufacturing drawings of the GLAS metering structure will be made available upon request.

Rationale: A baffle tube is necessary to prevent stray light from affecting the incoming signal.

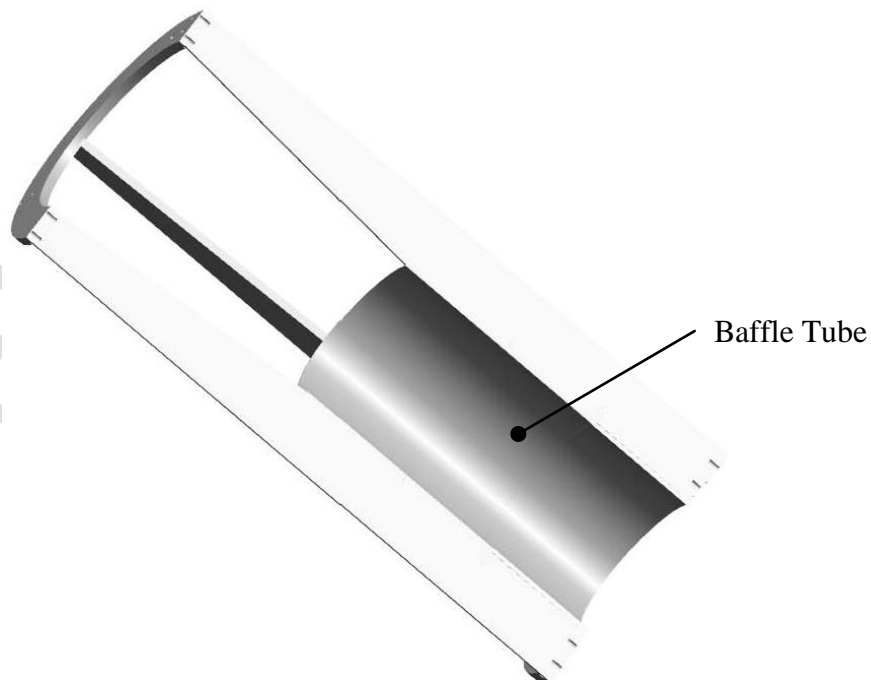
NASA desires the Contractor to choose a baffle design and thickness of their own liking, especially if such a design offers costs and schedule advantages and still meets the needs for ICD compliance, mechanical/stress margins, obscurations and FOV.

Traceability: Derived from GLAS heritage.

Verification Method: Analysis, Inspection, & Testing



**Figure 8-1 - GLAS Metering Structure with Baffle Tube**



**Figure 8-2 – A Cross-sectional View of the GLAS Metering Structure Illustrating the Lack of Internal Features in the Baffle Tube**

**TSCOPE035** – The metering structure shall provide an un-vignetted FOV of 1 degree on the diameter.

Rationale: Required to meet optical performance requirements.

Traceability: REC002 (ICESat-2-REC-REQ-0488, ATLAS Receiver Level IV Requirements Document)

Verification Method: Inspection

**TSCOPE036** – All surfaces of the metering structure, with the exception of holes and mating surfaces, shall be black anodize or an approved equivalent, as proposed by the Contractor and approved by GSFC.

Rationale: Anodizing the surfaces will provide increased corrosion resistance and satisfy stray light requirements.

Traceability: Derived from GLAS heritage.

Verification Method: Inspection

## 9.0 Interface Plate Assembly Requirements

**TSCOPE037** – The interface plate shall be black anodize or an approved equivalent, as proposed by the Contractor and approved by GSFC.

Rationale: Anodizing the interface plate will provide increased corrosion resistance.

Traceability: Derived from GLAS heritage.

Verification Method: Inspection

Released Version

## 10.0 Manufacturing Requirements

**TSCOPE038** – The Contractor shall ensure that all machined materials (beryllium and otherwise) are free of internal and thermal stresses induced during manufacturing and machining with a combination of acid etching and annealing.

Rationale: Internal stresses induced during the manufacturing process can lead to premature failure. For this reason it is prudent to ensure all internal stresses have been removed.

Traceability: Derived requirement

Verification Method: Inspection

**TSCOPE039** – All fracture critical metallic components, especially I-220-H components, shall be liquid penetrant inspected in accordance with NASA-STD-5009, Section 4.2 (TBR) after each manufacturing process, including but not limited to rough machining operations, fine machining operations and grinding operations. Liquid penetrant inspection should not be performed on the mirrors once the optical finishing processes have begun.

Note: Currently, this requirement specifies a “Standard” non-destructive evaluation (NDE), however, GSFC will perform a fracture mechanics analysis to determine if the limits of the Standard NDE flaw size detection are acceptable or if more refined flaw detection methods will be required. This analysis will be performed before manufacturing begins.

Rationale: Small surface fractures in materials such as I-220-H, titanium, stainless steels, etc. can quickly propagate and lead to catastrophic failure. Inspection will help identify and locate surface flaws. As a quality control measure NASA has developed a standard for the inspection of fracture critical metallic components.

Traceability: Derived requirement

Verification Method: Inspection

**TSCOPE040** – All traces of liquid penetrant shall be removed from inspected part immediately after inspection is complete.

Rationale: Liquid penetrant that is not removed prior to the next manufacturing process may act as a contaminant.

Traceability: Derived requirement

Verification Method: Inspection

**TSCOPE041** – All components shall be etched and heat treated to remove surface flaws and residual stress (subsequent inspections will be necessary to ensure surface flaw has been removed).

Rationale: Small surface fractures in materials such as beryllium can quickly propagate and lead to catastrophic failure. Etching will remove these flaws.

Traceability: Derived requirement

Verification Method: Inspection

Released Version

## 11.0 Electroless Nickel (EN) Plating & Optical Coating

**TSCOPE042** - Each pre-plated mirror shall be thermally cycled 3 times to the following specifications:

- A) Each cycle between the temperatures of  $177^{\circ}\text{C} +2/-6^{\circ}\text{C}$  and  $-40^{\circ}\text{C} +0/-30^{\circ}\text{C}$ .
- B) The dwell time at each thermal extreme between 30-45 minutes
- C) Thermal cycling hot/cold and cold/hot transition not to exceed  $1^{\circ}\text{C}/\text{minute}$ .

Rationale: It will be necessary to thermally cycle the mirrors prior to plating to ensure the mirrors do not experience “heat set” or a permanent distortion due to residual stress relaxation at elevated temperatures.

Traceability: Derived to achieve the workmanship quality necessary to meet performance requirements.

Verification Method: Testing and Inspection

**TSCOPE043** - Each pre-plated mirror shall maintain its shape to within 10 microns envelope around the true hyperbolic surface, as measured after three thermal cycles described in requirement TSCOPE042.

Rationale: It will be necessary to thermally cycle the mirrors prior to plating to ensure the mirrors do not experience “heat set” or a permanent distortion due to elevated temperatures.

Traceability: Derived to achieve the workmanship quality necessary to meet performance requirements.

Verification Method: Testing and Inspection (i.e. - Thickness mapping)

**TSCOPE044** – All surfaces of the primary mirror and secondary mirror shall be plated with electroless nickel.

Rationale: Both sides must be plated to prevent thermal distortion which may reduce throughput.

Traceability: TAR7 (ATLAS Technical Allocation Requirements Document, ICESat-2-ATSYS-REQ-0479)

Verification Method: Inspection

**TSCOPE045** - The electroless nickel plating shall be  $10 \pm 1.3$  microns thick on the back of each mirror.

Rationale: Plating thickness on the back of the mirror is specified to ensure it acts as a thermal counter-balance to the plating on the front of the mirror.

Traceability: Derived to meet performance requirements throughout the thermal environment.

Verification Method: Inspection

**TSCOPE046** – Prior to polishing, the minimum thickness of the electroless nickel plating on the front of each mirror shall be greater than or equal to 76.2 microns (0.003 inch).

Rationale: A minimum plating thickness is specified to ensure sufficient plating material is present to allow for proper polishing.

Traceability: Derived to meet performance requirements throughout the thermal environment.

Verification Method: Inspection

**TSCOPE047** - The electroless nickel plating on the front of each mirror shall be thick enough to allow a final thickness of greater than or equal to 25 microns after polishing.

Rationale: The polished plating must have sufficient thickness to prevent delamination.

Traceability: Derived to achieve the workmanship quality necessary to meet performance requirements.

Verification Method: Inspection

**TSCOPE048** - The Nickel bath shall be tuned to ensure the phosphorous content (%P) in the EN plating is greater than or equal to 10.5 %.

Rationale: Since the coefficient of thermal expansion (CTE) is related to phosphorous (P) content in the plating, and CTE is hard to measure directly, we specify %P. The required %P is estimated to be greater than or equal to 10.5%

Traceability: Derived to achieve the workmanship quality necessary to meet performance requirements.

Verification Method: Testing



**TSCOPE049** - The electroless nickel plating shall be baked out immediately after plating at a temperature of 163° C +10° C/-5° C for 2 hours ± 15 mins.

Rationale: Baking out the electroless nickel plating minimizes residual stresses.

Traceability: Derived to achieve the workmanship quality necessary to meet performance requirements.

Verification Method: Inspection

**TSCOPE050** - An Enhanced Aluminum Coating with a Protective Dielectric Overcoat shall be applied to all plated and polished optical surfaces on the Primary Mirror, the Secondary Mirror and their witness samples.

Rationale: In order to improve the reflectance of the optical surfaces. Enhanced Aluminum Coatings will significantly improve the performance of the telescope by improving the reflectance of each mirror.

Traceability: TAR7 (ATLAS Technical Allocation Requirements Document, ICESat-2-ATSYS-REQ-0479)

Verification Method: Inspection

**TSCOPE051** - The Contractor shall propose and GSFC will approve specifications for the aluminum coating and protective dielectric overcoat.

Rationale: Derived requirement. Specifications used on previous telescope are out-of-date and may no longer be valid. GSFC will look to industry experts to provide guidance.

Traceability: TSCOPE050

Verification Method: Inspection

**TSCOPE052** – Optical coatings shall comply with MIL-M-13508 (mirror, front surface aluminized) modified for Adhesion Testing (section 4.4.6) using the “quick-tape-removal” method IAW section 4.5.3.1 of Mil-C-48497A.

Rationale: It must be demonstrated that the coatings are sufficient to withstand durability expectations.

Traceability: TSCOPE050

Verification Method: Inspection

**TSCOPE053** – The witness specimens of the final optical coatings for all surfaces shall be electroless nickel plated and polished I-220-H beryllium.

Rationale: Witness samples will help to establish the quality and consistency of the process(es).

Traceability: Derived to achieve the workmanship quality necessary to meet performance requirements.

Verification Method: Inspection

**TSCOPE054** - The reflectance of the primary mirror, the secondary mirror and their witness samples after plating and coating shall be greater than 95 % at 532 nanometers (nm).

Rationale: This is necessary to meet instrument optical performance requirements

Traceability: TAR7 (ATLAS Technical Allocation Requirements Document, ICESat-2-ATSYS-REQ-0479)

Verification Method: Testing

## 12.0 MECHANICAL REQUIREMENTS

**TSCOPE055** – All major components of the telescope (i.e. - the Primary Mirror, the Secondary Mirror, the metering structure and the interface plate) shall be manufactured from the beryllium I-220-H billets supplied by GSFC.

Rationale: Beryllium I-220-H has been used successfully on several space-based telescopes. Its material properties (i.e. – its isotropic nature, homogeneity, yield strength, micro-yield strength, etc.) make it particularly well suited for use in space-based telescope designs.

Traceability: Derived from lessons learned.

Verification: Inspection

**TSCOPE056** - The maximum allowable mass for the telescope shall not exceed 22.5 kilograms (kg).

Rationale: This is the mass allocation from the ATLAS Technical Allocation Requirements document (ICESat-2-ATSYS-REQ-0479).

Traceability: TAR1 (ATLAS Technical Allocation Requirements Document, ICESat-2-ATSYS-REQ-0479)

Verification: Inspection

**TSCOPE057** - The maximum allowable volume for the telescope shall be length (Z axis, optical axis) 665.5 mm, and diameter 815.1 mm. The origin of the volume is the intersection of the interface plane to the optical bench and the optical (Z) axis.

Rationale: This is the volume allocation from the ATLAS Component Mechanical Interface Control Document (ICESat-2-MECH-IFACE-0590).

Traceability: ATLAS Component Mechanical Interface Control Document, (ICESat-2-MECH-IFACE-0590)

Verification: Inspection

**TSCOPE058** - The telescope shall allow for the routing of thermal hardware harness in a manner that does not negatively impact the optical performance of the telescope.

Rationale: The telescope metering structure and secondary mirror will require heater circuits and thermal sensors. The telescope design should include features to allow for routing of this hardware that does not interfere with the performance of the telescope

Traceability: TICD-022 (ATLAS Thermal Interface Control Document, ICESat-2-THM-IFACE-0214)

Verification Method: Inspection

**TSCOPE059** – The telescope shall allow for attachment of a grounding wire of sufficient size and conductance to ground all electrically conductive materials via a continuous conductive path with resistance less than  $1.0 \times 10^{12}$  ohms.

Rationale: The telescope design should include features that allow grounding wires to be run to preclude the possibility of an uncontrolled electrical discharge event.

Traceability: ESR131 (ATLAS Electrical Systems Requirements, ICESat-2-SYS-REQ-0189)

Verification Method: Testing and Inspection

## 13.0 ENVIRONMENTAL REQUIREMENTS

### 13.1 Mechanical Environment

**TSCOPE060** - The fundamental frequency of the telescope shall be greater than or equal to 100 Hertz (Hz).

Rationale: Telescope fundamental frequencies should avoid instrument assembly and observatory induced excitation frequencies.

Traceability: CERD4 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis and Test (testing performed at GSFC).

**TSCOPE061** - Structural analysis of the telescope shall show positive margins of safety (MS) for ultimate and yield failures verified by a detailed stress analysis that assesses all primary and secondary structure, joints, and fasteners for the limit load of 22.9 g's and the appropriate factor of safety (FS) specified in Table -1.

**Table -1 - Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads for Non-glass and Non-pressurized ATLAS Components**

Type	Static	Sine	Random/ Acoustic <sup>1</sup>
Metallic Yield	1.25	1.25	1.6
Metallic Ultimate	1.4	1.4	1.8
Stability Ultimate	1.4	1.4	1.8
Beryllium Yield	1.4	1.4	1.8
Beryllium Ultimate	1.6	1.6	2.0
Composite Ultimate	1.5	1.5	1.9
Bonded Inserts/Joints Ultimate	1.5	1.5	1.9

<sup>1</sup>Factors shown should be applied to statistically derived peak response based on root mean square (RMS) level. As a minimum, the peak response will be calculated as a 3-sigma value.

Rationale: Quasi-static acceleration represents the combination of steady-state accelerations and the low frequency mechanically transmitted dynamic accelerations that occur during launch. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements. The margin of safety is defined as follows:

$$MS = \{ \text{Allowable Stress (or Load)} \div (\text{Applied Limit Stress (or Load)} \times FS) \} - 1$$

Traceability: CERD7 (ATLAS Component Environmental Requirements Document,

ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis and Test (testing performed at GSFC).

**TSCOPE062** – The telescope shall show positive margins of safety for ultimate and yield failures in a structural analysis using the loads specified in Table-2 and the appropriate factor of safety specified in Table -1.

**Table-2 - Sinusoidal Vibration Levels for ATLAS Components**

Test	Axis	Frequency (Hz)	Level (peak)	Sweep Rate (octaves/min)
Proto-flight	Thrust	5 – 20	0.63 inches D.A.	4
		20 – 50	12.5 g	
	Lateral	5 – 20	0.63 inches D.A.	4
		20 – 50	12.5 g	

Rationale: Sine vibration loads simulate launch vehicle loading conditions. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements.

The margin of safety is defined as follows:

$$MS = \{ \text{Allowable Stress (or Load)} \div (\text{Applied Limit Stress (or Load)} \times FS) \} - 1$$

These levels will be updated using a combination of coupled loads results and base-drive analysis.

Traceability: CERD11 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis and Test (testing performed at GSFC).

**TSCOPE063** – The telescope shall show positive margins of safety for ultimate and yield failures in a structural analysis using the protoflight loads specified in Table -3 and the appropriate factor of safety specified in Table -1.

**Table -3 - Random Vibration Levels for ATLAS Components (from GEVS Table 2.4-3)**

Random Levels for Components Weighing Less Than 22.7 kg (50 lbs.)	
Frequency (Hz)	Proto-flight

	ASD (g <sup>2</sup> /Hz)
20	0.026
20-50	+6 dB/Octave
50-800	0.16
800-2000	-6 dB/Octave
2000	0.026
Overall (g <sub>rms</sub> )	14.1
Duration (minutes)	1

**Rationale:** The random vibration environment results from the coupling of structure-borne random vibration with the acoustic noise inside the payload fairing. The purpose of the structural analyses is to show compliance with the mechanical/structural design and test requirements.

The margin of safety is defined as follows:

$$MS = \{ \text{Allowable Stress (or Load)} \div (\text{Applied Limit Stress (or Load)} \times FS) \} - 1$$

Random vibration loads will be statistically derived peak responses based on RMS level from the specification in Table -3. As a minimum, the peak responses will be calculated as 3-sigma value.

**Traceability:** CERD13 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

**Verification:** Analysis and Test (testing performed at GSFC).

**TSCOPE064** – The Contractor shall perform an acoustic loads analysis showing positive margins of safety for ultimate and yield failures using the loads specified in Table -4 and the appropriate factor of safety specified in Table -1.

**Table -4 - Observatory Acoustic Levels**

1/3 Octave Band Center Frequency (Hz)	Max. Predicted Environment (dB)	Proto-flight Test Level (dB)
	126	129
	127	130
32	126	129
40	129	132
50	132	135
63	134	137
80	135	138
100	135.5	138.5
125	136	139
160	135	138
200	133	136
250	133.6	136.6
315	132	135
400	131	134
500	130	133
630	128.5	131.5
800	127	130
1000	126	129
1250	122	125
1600	120.5	123.5
2000	121	124
2500	118	121
3150	117.5	120.5
4000	116	119
5000	114.5	117.5
6300	113.5	116.5
8000	114	117
10000	114.5	117.5
OASPL	141.2	144.2
Duration	60 sec	60 sec

**Rationale:** Acoustic noise occurs during launch, at lift-off and in the transonic region. Structural analysis of ATLAS flight components may wring out design problems before flight hardware testing.

The margin of safety is defined as follows:

$$MS = \{ \text{Allowable Stress (or Load)} \div (\text{Applied Limit Stress (or Load)} \times FS) \} - 1$$

Acoustic loads will be statistically derived peak responses based on RMS level from the specifications in Table -4. As a minimum, the peak responses will be calculated as 3-sigma value.

**Traceability:** CERD15 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )



Verification: Analysis and Test (testing, if required, performed at GSFC).

**TSCOPE065** – The Contractor shall perform a shock loads analysis showing positive margins of safety for ultimate and yield failures using the loads specified in Table -5 and the appropriate factor of safety specified in Table -1.

**Table -5 – ATLAS Component Shock Response Spectrum (Q = 16)**

Frequency (Hz)	Shock Level Protoflight/Qualification (g)
100	70
1000	2400
10000	2400

Rationale: Certain ATLAS components may be sensitive to shock loads, such as such as observatory separation, boom deployment, etc. Evaluating shock sensitivity of ATLAS flight components may wring out design problems before flight hardware testing.

The shock levels given in Table -5 assume that ATLAS is located at least 60 centimeters (2 feet) from a shock source. If ATLAS is farther than 2 feet from a shock source the methods specified in General Environmental Verification Specification (GEVS), GSFC-STD-7000, Appendix A-5 to A-12 can be used to calculate shock levels from pyrotechnic devices

Traceability: CERD18 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis and Testing (testing, if required, performed at GSFC)

**TSCOPE066** – The telescope shall be designed to meet all performance requirements while operating at a pressure of  $1.3 \times 10^{-12}$  Newton/meter<sup>2</sup> (N/m<sup>2</sup>) ( $1 \times 10^{-14}$  Torr).

Rationale: The instrument will operate in a vacuum environment.

Traceability: CERD20 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis and Test (Thermal vacuum testing performed at GSFC).

**TSCOPE067** – The telescope shall survive exposure to a maximum depressurization rate of 6.2 kiloPascal (kPA)/second (s), 0.9 pounds per square inch (PSI)/s, experienced during launch and ascent, without any damage or degradation of performance.

Rationale: The instrument will operate after being exposed to de-pressurization during launch and ascent.

Traceability: CERD21 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis

**TSCOPE068** – Venting analyses of the telescope shall show positive margins of safety for ultimate and yield failures using the loads equal to twice those induced by the maximum pressure differential specified in TSCOPE067 and the appropriate factor of safety specified in Table -1.

Rationale: This analysis verifies that ATLAS components susceptible to pressure loadings will survive exposure to the launch pressure profile.

Traceability: CERD23 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis

**TSCOPE069** – The telescope shall show positive margins of safety for ultimate and yield failures in a structural analysis using the maximum on-orbit temperature gradients shown in a thermal analysis using the environments specified in TSCOPE071 and TSCOPE072 and the appropriate factor of safety specified in Table -1.

Rationale: This analysis verifies structures will survive on orbit stresses due to temperature loading and coefficient of thermal expansion mismatches.

Traceability: CERD24 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis and Test (Thermal vacuum testing performed at GSFC).

**TSCOPE070** - The telescope shall meet all performance requirements after exposure to relative humidity levels of 35% to 70% (TBR).

Rationale: Humidity levels are important to reduce or eliminate the possibility of an electro-static discharge (ESD) event which could damage flight hardware.

Traceability: CERD30 (ATLAS Component Environmental Requirements Document, ICESat-2-ATSYS-REQ-0517 )

Verification: Analysis

### 13.2 Thermal Environment

**TSCOPE071** – The telescope shall meet all performance requirements when operating in a temperature range of -10 to +45 degrees C.

Rationale: This defines the telescope operational temperature environment.

Traceability: TICD-034 (ATLAS Thermal Interface Control Document, ICESat-2-THM-IFACE-0214)

Verification: Analysis and Test (testing performed at GSFC).

**TSCOPE072** – The telescope shall meet all performance requirements after being exposed to the survival temperature range of -40 to +50 degrees C.

Rationale: This defines the telescope survival temperature environment.

Traceability: TICD-034 (ATLAS Thermal Interface Control Document, ICESat-2-THM-IFACE-0214)

Verification: Analysis and Test (testing performed at GSFC).

**TSCOPE073** – The telescope thermal analysis performed as part of the verification of requirements TSCOPE071 & TSCOPE072 shall use only the optical properties contained in Table-6.

Rationale: This list is taken from the ATLAS Thermal Analysis Approved Optical Properties List (ICESat-2-THM-LIST-0520). All optical properties must be verified by the NASA GSFC Coatings Committee. All approved optical properties, including beginning- and end-of-life values, are given in Table-6.

Traceability: TICD-087 (ATLAS Thermal Interface Control Document, ICESat-2-THM-IFACE-0214)

Verification: Analysis

**Table-6: Optical Properties**

Contamination &amp; Coatings Engineering Branch

Code 546

Goddard Space Flight Center Thermal Coatings Committee

Committee Members: L. Kauder, Jack Triolo, Ted Michalek, Mark Hasegawa, Raymond Levesque,

Wanda Peters

9-Sep-10

Coating	Location	Notes	BOL Cold case		EOL Hot case (150 Days)	
			$\alpha_S$	$\epsilon_H$	$\alpha_S$	$\epsilon_H$
Vapor Depsoited Gold	int	values here represent a polished surface	N/A	0.04	N/A	0.02
Z306 Black Paint	ext	no sun view	N/A	0.90	N/A	0.86
Z307 Black Paint	ext	no sin view	N/A	0.89	N/A	0.85
Germanium Black Kapton (GBK)	ext		0.49	0.81	0.53	0.75
Irridite Aluminum	int		N/A	0.19	N/A	0.05
Anodized Aluminum	int		N/A	0.89	N/A	0.72
M55J composite	int		N/A	0.76	N/A	0.74
Tiodized Titanium	int	will need a representative sample to verify properties	N/A	0.89	N/A	0.34
Silver Teflon Tape (5mil)	ext	shallow sun view	0.07	0.78	0.20	0.72
Silver Teflon Tape ITO (5mil)	ext	shallow sun view	0.08	0.78	0.20	0.72
Silver Teflon Tape (10mil)	ext	shallow sun view	0.08	0.85	0.21	0.78
Silver Teflon Tape ITO (10mil)	ext	shallow sun view	0.09	0.85	0.21	0.78
OSR/ ITO	ext		0.07	0.80	0.18	0.76
Z93 White Paint	ext		0.15	0.91	0.22	0.87
Kapton/VDA film (3 mil)	ext		0.45	0.79	0.57	0.74

Kapton/VDA film (2 mil)	int	Kapton facing out.	N/A	0.74	N/A	0.70
Kapton/VDA film (3 mil)	int		N/A	0.79	N/A	0.74
Black Kapton film ( 1 mil)	ext		0.91	0.83	0.95	0.79
Anodized Beryllium	ext	will need a representative sample to determine properties	TBD	TBD	TBD	TBD
Gold Plated Beryllium	ext		0.18	0.07	0.25	0.02
Nickel Plated Beryllium	ext		0.37	0.11	0.41	0.07
Fused Silica Glass	int		N/A	0.80	N/A	0.76
FS72H Protected Aluminum Coating on Beryllium	ext	will need a representative sample to determine properties	TBD	TBD	TBD	TBD
Note: The GSFC coatings committee recommends the above values given, except as noted above. This does not imply the acceptance of any coatings values not listed on this table.						

### 13.3 Contamination Control Requirements

**TSCOPE074** - The contractor shall establish the specific cleanliness requirements to minimize performance degradation and delineate the approaches to meet the ATLAS Project requirements in accordance with the ATLAS Contamination Control Plan (ICESat-2-ATSYS-PLAN-0297).

Rationale: A sufficiently clean manufacturing environment is required to ensure that the telescopes optical performance is not degraded in any way due to any fabrication processes.

Traceability: ATLAS Contamination Control Plan (ICESat-2-ATSYS-PLAN-0297).

Verification Method: Inspection

## APPENDIX A: Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
ASD	Acceleration spectral density
ASTM	American Society for Testing and Materials
ATLAS	Advanced Topographic Laser Altimeter System
ATSYS	ATLAS Systems Engineering
BFL	Back Focal Length
BOL	Beginning of life
C	Celsius
CERD	Component Environmental Requirements Document
cm	Centimeter
CM	Center of Mass or Configuration Management
CTE	Coefficient of Thermal Expansion
D	Diameter
DA	Direct amplitude
dB	Decibel
EFL	Effective Focal Length
EN	Electroless Nickel
EOL	End of Life
ESD	Electrostatic Discharge
ESR	Electrical Systems Requirement
Ext	External
FOV	Field of View
FS	Factor of safety
Ft	Foot
g	Acceleration due to gravity at the Earth's surface
GBK	Germanium Black Kapton
GEVS	General Environmental Verification Specification
GLAS	Geoscience Laser Altimeter System
grms	Acceleration due to gravity at the Earth's surface root mean square
GSFC	Goddard Space Flight Center
Hz	Hertz
IAW	In Accordance With
ICD	Interface Control Document
ICESat-2	Ice, Cloud, and Land Elevation Satellite 2
ID	Inner Diameter
IFACE	Interface
Int	Internal
ITO	Indium Tin Oxide

<b>Abbreviation/ Acronym</b>	<b>DEFINITION</b>
kg	Kilogram
kPa	Kilopascal
lbs	Pounds
m	Meter
M1	Primary Mirror
M2	Secondary Mirror
MECH	Mechanical
MIL	Military
Min	Minute
MIS	Management Information System
mm	Millimeter
mrاد	milliradians
MS	Margin of safety
MSFC	Marshall Space Flight Center
N	Newton
N/A	Not Applicable
nm	Nanometers
NASA	National Aeronautics and Space Administration
NDE	Non-destructive Evaluation
OASPL	Overall Sound Pressure Level
OD	Outer Diameter
OPT	Optic
OSR	Optical Solar Reflector
Pa	Pascal
PDL	Product Design Lead
PG	Procedures and Guidelines
PSI	Pound per square inch
Q	Attenuation
REC	Receiver
REQ	Requirement
Rev	Revision
RMS	Root mean square
RPT	Report
s	Second
SCORE	Signature Controlled Request
Sec	Second
SMA	Safety and Mission Assurance
SOW	Statement of Work
SPEC	Specification
STD	Standard
SYS	Systems Engineering

<b>Abbreviation/ Acronym</b>	<b>DEFINITION</b>
TAR	Technical Allocation Requirements Document
TBD	To Be Determined
TBR	To Be Resolved
THM	Thermal
TICD	Thermal Interface Control Document
TN	Technical Note
VDA	Vapor Deposited Aluminum
$\alpha_s$	Solar Absorptivity
Å rms	Angstrom Root Mean Square
°C	Degrees Celsius
$\epsilon_H$	Hemispherical Emissivity
%P	Phosphorous Content
µm	Micrometer
µrad	Microradians
Ø	Diameter